26th International **Vienna Motor Symposium** 28 – 29 April 2005

As in every preceding year the 26th International Vienna Motor Symposium was an outstanding event for leading engineers from all over the world. They presented their most recent development results and gave an outlook on future trends. This article presents the lectures of each session and gives an overview about their contents. Every lecture and discussion was simultaneously translated to German or English respectively during the event.

Author
Hans Peter Lenz, President of the Austrian Society of Automotive Engineers (ÖVK)

Author

Hans Peter Lenz,
President of the
Austrian Society of
Automotive Engineers
(ÖVK)

1 Introduction

After a welcome fanfare, **Figure 1**, which was performed by the members of the orchestra of the Technical University of Vienna, and composed by the conductor, **Professor Lenz** welcomed the participants to the 26th International Vienna Motor Symposium.

As in previous years, Prof. Lenz pointed out that a large number of applications for participation had had to be turned down as the capacity of the venue is restricted to 1,000 participants. Nevertheless, the quotas of companies were met and assured comprehensive attendance at the Symposium by all important representatives of the world of automotive engineering.

The termination of Fiat-GM Powertrain, Prof. Lenz emphasized, had necessitated modifications to the programme, which had originally included two interesting lectures by representatives of Fiat-GM. This organisation had operated for five years with great commitment and experienced a successful development but was terminated in February 2005.

Shortly before the start of the Symposium, Fiat's new Board had prohibited the publication of these lectures after Dr. Demel, Fiat's head of passenger car operations, had left the company. Prof. Lenz stated that he considered this an utterly regrettable move. The problem was, of course, resolved, and instead of Fiat's papers, two excellent lectures were presented by Meta and AVL.

After the opening plenary session the audience split up into two parallel sessions at which technical presentations were made. The sessions were headed by **professors H. Eichlseder**, **B. Geringer**, **G. Jürgens**, and **R. Pischinger**, **Figure 2** and **Figure 3**.

An impressive and very comprehensive exhibition of new engines, components and vehicles provided an excellent complement to the lectures, **Figure 4**, **Figure 5** and **Figure 6**.

Accompanying persons were offered a culturally sophisticated social programme which included an excursion taking participants along the "Traces of Romanesque, Gothic and Baroque in the Foothills of the Alps", as well guided tours of the Vienna Hofburg (Imperial Castle) and a number of palaces in its vicinity, a walk through the "Scots" quarter, one of the treasures of Vienna, and a guided tour of the historic and modern concert halls of the world famous "Musikverein" building.

Upon the invitation of the Mayor of Vienna, the conference participants and accompanying persons spent the evening in a pleasant atmosphere in the splendid rooms of the Vienna City Hall, where the original "Hoch- und Deutschmeister" band played.

2 Plenary Opening Session

In this session, two heated issues were debated.

The hybrid drive system which had lately been discussed widely in the media, and the reliability of electronic components.

Japanese vehicle manufacturers, in particular Toyota, have succeeded in convincing the world public of the advantages of their hybrid vehicles which undoubtedly feature top-quality technology solutions. European car makers have been attacked by the media for having been caught napping by this technology. This is, however, not correct, if you think of the hybrid vehicles developed by VW, or the three hybrid generations produced by Audi which even included a diesel-engine powered hybrid vehicle.

Figure 1: Welcome Fanfare

Figure 2: Plenary session in the Festsaal

The two lectures dealing with these issues were characterised by their high factual accuracy.

The first lecture was presented by a neutral party, i.e. major supplier to the automotive industry, the Chairman of the Board of ZF Friedrichshafen, **Dr.-Ing. E.h. S. Goll** (lecturer), **Figure 7**, and **Dr.-Ing. H.-J. Domian**: "From the Standard Driveline to the Hybrid Drive? The Supplier's Point of View":

ZF Friedrichshafen offers a wide range of electrical drives and is capable of delivering highly integrated hybrid systems, including networked component control and relevant operating strategies. Reliable forecasts on the future perspectives of hybrid drive technology cannot yet be made. Hybrid drive offers advantages in terms of fuel economy, emission levels and driving dynamics, but involves higher costs and increased complexity as compared to conventional drives. The well-known demands made upon conventional drives also apply to hybrid drives. The cost-benefit ratio must therefore take into account the specific needs of markets, and applications for further improvement resulting from an optimisation of conventional drives must not be overlooked in this context.

Thanks to the new co-operation between DaimlerChrysler and GM in the area of hybrid drives, participants were informed of the perspectives of both companies. **D.M. Hancock**, Vice President, General Motors Powertrain, Pontiac, and **Dr.-Ing. L. Mikulic**, Vice President – Powertrain Development,

Figure 3: Session in the Zeremoniensaal

Figure 4: Exhibition Audi

Mercedes Car Group-DaimlerChrysler AG, Stuttgart, presented their views. **Figure 8** shows the two lecturers.

DaimlerChrysler and General Motors took the decision to develop jointly a "two-mode full hybrid system". The experience of both companies has shown that considerable cost savings can be expected from these synergies.

General Motors have been producing the first "two-mode full hybrid system" for transit buses since 2003. These buses have operated successfully in 18 cities worldwide. In 2004, General Motors started the production of the first hybrid pickup-trucks. DaimlerChrysler has been developing alternative powertrains for passenger cars since 1982. Last year it presented a combination of a 184 kW-V8-diesel engine and a 50 kW electric motor.

It should be kept in mind that the customer ultimately determines the success of a new technology, reduced fuel consumption is particularly important in terms of actual operations and not only in certification cycles.

The forecast is clear:

- There is no single solution: hybrid, gasoline and diesel powertrains will co-exist in the future, each used in applications where they create the greatest value.
- Hybrids offer unique opportunity to offset vehicle sale losses not accessible with conventional powertrains.
- GM and DC are co-developing hybrid solutions and are open to collaborating with other OEMs.

The second topic addressed by the plenary was the reliability of electronic systems from the perspective of the Siemens company. In this area, too, the media have exerted considerable pressure on the automotive engineering industry.

Dr.-Ing. K. Egger, Member of the Board, Siemens VDO Automotive AG, Regensburg, **Figure 9**, presented his lecture entitled: "Electronics as a Reliable Key Technology for Future Powertrain Concepts":

The fact is frequently ignored that 50 % of all breakdowns of electronic systems are due to defects of batteries and cables. Furthermore, the risk of breakdowns of relatively new vehicles has been drastically declining for many years.

Today electronics contribute to a high degree to improving the safety of cars and to reducing fuel consumption and emissions. Future innovations to powertrains – from

Figure 5: Exhibition BMW

new combustion processes to exhaust gas after treatment and hybrid drives – will rely on even more electronic components. Today electronic systems already show a high degree of reliability. As ever more functions are performed by electronic systems, new challenges have to be addressed: the complexity of these systems should be minimised by means of software platforms and modular hardware, and the remaining complexity should be managed by pre-defined processes in such a way as to eliminate errors. In these efforts, the entire life cycle of a vehicle, and not only its series production, must be considered.

3 Has Emission Reduction Reached its Limits?

This section addressed the question as to whether emission limits for passenger cars and utility vehicles are already so stringent that, from the perspective of medicine and air quality, it may be argued that enough has been achieved.

Dr. N. Metz (lecturer), **Dr. rer. nat. J. Theis**, BMW Group, Munich: "Passenger Car Emissions: A Problem Solved?":

The lectures described the progress achieved in reducing CO_2, HC, NO_X and particulate emissions from gasoline and diesel engine powered passenger cars since 1970. The lecturer quantified emissions from all sources and indicated the share of emissions from passenger cars in total emissions in Germany, broken down by the individual emission components for the year 2000. Using a forecast model, emissions from passenger cars in Germany were forecast until the year 2030. On the basis of the expected development of emissions from all sources, a comparison between the trend of emissions from passenger car traffic and their effect on air quality measured at kerbside and urban background stations was made. The forecast of the air quality trend until the year 2030 was made on the basis of the expected development of emission levels. Air quality data demonstrate that already now CO and HC emissions are significantly below future limit values. Under adverse meteorological conditions, NO_2 and PM_{10} emissions may, however, exceed the maximum permissible levels defined by the EU for air quality. Whereas for gasoline engine powered vehicles the future limit values can easily be met, and the particulate emission problem of diesel-engine powered vehicles can be solved by means of particulate traps, $N0_2$ emissions remain an area of concern.

Dr. rer. nat. E. Jacob, MAN Nutzfahrzeuge Gruppe, Nuremberg: "Emission Limits for Future Commercial Vehicle Engines: A Balancing Act between Potential and Benefits":

The introduction of the Euro 4 technology in commercial vehicles in 2005 will result in a lowering of PM emission limits to 2.7 % of the maximum permissible values of 1988. Thus it can be forecast that by 2020 particulate emissions from commercial vehicles in Germany will be brought down to one quarter of particulate emissions recorded in 2000, despite ever increasing mileages. As commercial vehicles account for a mere 7 to 10 % share of anthropogenic particulate emissions in Europe, the lowering of Euro 4/5 PM limits for commercial vehicles by 33 % to 20 mg/kWh (ETC) will be sufficient in the future and will constitute the final limit for particulate emissions. This is scientifically proven by the threshold value for the secondary genotoxic effect of diesel particulates which was repeatedly demonstrated in medical tests. A reduction below 20 mg PM/kWh would result in a disproportionately high increase in fuel consumption and the need for excessive maintenance.

With regard to the future NO_X emission limits, the lecturer advocated the lowering of the Euro 5 limit by 50 % to 1 g NO_X/kWh by 2012/13. Accordingly, NO_X emissions from heavy-duty commercial vehicles could be reduced to less than one quarter of the levels recorded in Germany in 2000. Lowering NO_X emission limits for commercial vehicles to less than 1 g/kWh from 2012/3 onwards will

Figure 6: Exhibition AVL. f.r.t.l.: Prof. Dr. Helmut List, AVL Graz; Gianpietro Brustolin, AVL Borgaro; Eng. Paolo Martinelli, Ferrari Sportiva; Dr. Peter Schöggl, AVL Graz; Dr. Heinz Fachbach, AVL Graz

Figure 7: Dr.-Ing. E.h. Siegfried Goll, ZF Friedrichshafen AG

Figure 8: Daniel M. Hancock, GM Powertrain (right); Dr.-Ing. Leopold Mikulic, Daimler Chrysler AG (left)

Figure 9: Dr. Klaus Egger, Siemens VDO Automotive AG

have no significant effect on NO_X emissions from mobile sources by 2020, as airline traffic and durable off-road engines are responsible for a large share of NO_X emissions.

Nevertheless, the question arises whether it will be possible to meet the NO_X emission limit of 0,3 g/kWh in the USA, whereas in Europe the limit is 1,0 g/kWh. After all, this represents a 50 % difference in emissions from commercial vehicles in Germany. This situation needs clarification.

The future legislation in connection with Euro 6 should aim at a global harmonisation of test cycles (WHDC) and standards for better quality and cleaner fuels. Clean fuels and low-ash lubricants guarantee the long-term stability of engines producing minimum emissions,

Univ.-Prof. Dr. med. J. Bruch, Universitätsklinikum Essen and IBE GmbH, Marl: "The Toxic Potential of Diesel Particulate Emissions and the Significance of Threshold Values for Risk Assessment":

Long-term exposure to ambient particulate matter, including diesel emission particles is associated with higher risks of cardiovascular diseases and lung cancer. Epidemiological studies have demonstrated that a threshold value cannot be determined. Toxicological data show a mutagenic potential of the organic extracts from diesel soot. Long-term high-dosage inhalation tests in rats have demonstrated dosage-related cancerogenic effects. Dosiometric calculations have revealed the enormous significance of particulate matter for the development of tumours. Mechanistic studies have confirmed the pronounced effect of inflammatory processes on the formation of tumours due to exposure to particulates, including oxidative DNA adducts and mutagenicity. Secondary genotoxic effects are assumed to act as an underlying mechanism. Effective defence mechanisms were identified which determine thresholds in the critical intermediate steps in the tumour path. Experimental studies of different designs using varying dosages confirmed thresholds for inflammation, genotoxicity and mutagenicity. By using multi-dose doubling step (DDS) a reference to a standard dust of low toxicity, such as corundum, was established. The threshold dose for critical effects caused by a test sample can be assigned to the applicable DDS, harmfulness (nocivity) is expressed as a toxicity dose doubling step category (TDDS). The real world of dust-related genotoxicities encompasses TDDS 0 (zero) for corundum and TDDS 4 (four) for crystalline silicia DQ 12. For a diesel soot sample low toxicity of TDDS 1 was established.

It can be assumed that ambient particles exhibit a very broad range of intrinsic toxicities. This heterogeneous pattern of toxicities which also applies to diesel particles, combined with the threshold character of particle toxicity, triggers calls for further developments in exhaust gas technology and requires a risk assessment that takes into account all of these factors. In conclusion, it can be summarized that:

- There is no threshold value for particulate concentrations in the ambient air below which harmful effects on human health could be ruled out. The assumption that even minimum amounts of particulate matter in the air could cause health problems is not justified.
- Much rather, the goal must be to minimise toxic emission sources instead of reducing all particulate emissions worldwide.
- Diesel soot compared to other dusts, e.g. quartz, is relatively less harmful.

4 Diesel Injection

Dr.-Ing. S. Kampmann (lecturer), **Dr.-Ing. U. Dohle**, **Dr.-Ing. J. Hammer**, **Dipl.-Ing. F. Boecking**, Robert Bosch GmbH, Stuttgart: "Common Rail Systems for Meeting Future EU Emission Standards":

The requirements for future diesel applications are manifold: lower raw emission levels combined with maximum engine performance, noise emission characteristics comparable to those of gasoline engines, and record fuel economy.

In order to meet all of these requirements it is necessary to assure the highest accuracy in metering fuel injection quantities into the combustion chamber. In this process, state-of-the-art common rail injection systems will play a key role in future diesel technology.

The functional range of Bosch common rail systems of the second to the fourth generations offers vehicle manufacturers a wide selection of injection technology options which will enable them to meet the aforementioned demands in combination with engine design and exhaust gas aftertreatment measures.

With a view to minimising raw emissions over the entire service life of vehicles a further improvement of the robustness of common rail systems will be required. A holistic approach was presented and the core features of components, processes and systems were described in detail using the Bosch – CRS3 as an example.

BEng. H. Tokuda (lecturer), **Dr. S. Itoh**, **BEng. M. Kinugawa**, Denso Corporation, Aichi-ken, Japan; **MEng. N. Shirabe**, Nippon Soken, Inc., Aichi-ken, Japan: "Denso Common Rail Technology to Successfully Meet Future Emission Regulations":

The Common Rail System (CRS) is a new technology for fuel injection systems that has revolutionized diesel engines for trucks and passenger cars. Denso has continued to work on CRS technologies since it produced the world's first such system for trucks in 1995.

These pioneering efforts bore further fruit in 2002, when Denso created a common rail system featuring an amazing injection pressure of 180 MPa. A two-litre, four-cylinder engine-powered passenger car employing this system delivered a specific power of 50 kilowatts per litre, with the potential to clear Euro 4 emissions regulations without the use of a diesel particulate trap. This report described how Denso drew on its technology to improve engine output by raising the injection pressure to 200 MPa and met stricter emissions regulations through a simple and innovative Group Holes Nozzle concept (GHN). Tests demonstrated that it is possible to increase specific power from 50 kilowatts per litre to more than 70 with 200 MPa injection pressure. A more homogeneous lean air-fuel mixture can be obtained with the aid of the Group Holes Nozzles, and by the addition of a cooled EGR, pre-mixed combustion or quasi-premixed combustion can be achieved. This has underscored the potential of Denso's CRS technology in clearing future emissions standards.

Dipl.-Ing. D. Jovovic, **Dr. M. Kronberger** (lecturer), **Dipl.-Ing. R. Pirkl**, **Dr.-Ing. P. Voigt**, Siemens VDO Automotive AG, Regensburg: "The Piezo Unit Injector System for Volkswagen Diesel Engines":

With ever more stringent emissions standards applying to diesel engines for passenger cars, the danger is growing that increased design efforts in the development of diesel engines as compared to gasoline engines will not be offset by heightened customer benefits. The diesel injection system continues to be the key factor determining progress and constitutes an essential cost element. With the newly designed Piezo-actuated Unit Injection, Siemens VDO and Volkswagen have made a vital contribution to the competition among different injection concepts. The lecture described the stages in the evolution of systems, from the initial concept to the final version which met all specifications and cost targets.

The objective was for the entire Passat car class to comply with the Euro 4 emission limits without having to use a particulate trap. The factors that determined the success of this approach were a careful analysis and design of engines for optimum pressure, metering accuracy and injection curves over the entire engine map. Piezo elements are used as actuators and sensors for several closed loop control circuits with the aid of which use was made of all advantages of Piezo technology, such as engine noise control, assuring the required metering precision under all operating conditions over the entire service life of the engine.

The Piezo Unit Injector has been produced in a factory in Germany which was built jointly by VW and Siemens VDO and opened in 2004. The electronic control unit was developed by Siemens VDO.

In the course of the development work on injection hydraulics and Piezo technology a new potential for improvements manifested itself. This includes higher efficiency and peak pressure levels as well as an improved part lift ability of the Piezo injector. The two companies intend to draw on this potential in the future. Homogeneous diesel combustion will act as a driving force behind future improvements, especially in Piezo technology.

5 New Gasoline Engines 1

Dipl.-Ing. S. Knirsch (lecturer), **Dipl.-Ing. M. Kerkau**, **Dr.-Ing. H. J. Neußer**, Dr. Ing. h. c. F. Porsche AG, Weissach: "The New Flat-Six Engines for the Porsche 911 Carrera":

After 28 years, Porsche now offers again two different power variants of its flat-six engine, both of which are destined for the Porsche 911 Carrera. The output data of the service-proven 3.6 litre unit have been specifically optimized and the resulting 239 kW nominal power and 370 Nm maximum engine torque will satisfy even most ambitious customer expectations. The new 3.8 litre variant with its 261 kW power output and 400 Nm maximum torque lends the 911 Carrera S superior driving performance in the sports-car segment and, at the same time, closes the gap in the range of Porsche's top products - the 911 GT3 and 911 Turbo. These excellent results have been achieved by increasing the engine displacement from 3.596 cm^3 to 3.824 cm^3, by precisely optimizing the gas-exchange system on the intake and exhaust side and by further improving the cylinder head cooling concept which allowed the compression ratio to be raised to e = 11.8.

The specific power output of 68.3 kW/l and specific torque of 104.6 Nm/l are top-class values in the naturally aspirated high-performance engine category.

The two new engines remain clearly under all the currently applicable emission levels worldwide, such as Euro 4 and LEV for example. At the same time, the NEDC fuel consumption of the 3.6l variant was reduced by 1 % to 11.0 l/100 km, while the 3.8l Carrera S features a NEDC fuel economy of 11.5 l/100 km which makes it stand out among its competitors in the top-class segment.

Dr.-Ing. R. Szengel (lecturer), **Dipl.-Ing. U. Kirsch**, **Dr.-Ing. B. Ebel**, **Dipl.-Ing. S. Lieske**, **Dipl.-Ing. F. Reschke**, Volkwagen AG, Wolfsburg: "Volkswagen's New V6 Engine Generation with Direct Fuel Injection":

The Volkswagen V-engine series was thoroughly revised with a view to meeting ever more exacting demands. The development focused mainly on introducing direct fuel injection for gasoline engines and increasing the displacement to 3.6 dm^3 especially for the US market, without making changes to the vehicle package. The direct fuel injection technology offers new opportunities for complying with future emission limits and reducing fuel consumption. Exhaust gas emission limits in accordance with EU4 and LEV2 can be met without requiring secondary air injection into the exhaust system. The new engine has a maximum torque of 360 Nm and a rated output of 206 kW at 6200 rpm. For the European market, a 3.2 dm^3 version with a maximum torque of 330 Nm and a rated output of 184 kW is offered.

A. Falkowski, **M. McElwee** (lecturer), DaimlerChrysler Corp., Auburn Hills, USA; **Dr.-Ing. U. Geiger**, INA-Schaeffler KG, Herzogenaurach: “Features and Development of the DaimlerChrysler 5.7l HEMI Engine Multi-Displacement System”:

A cylinder cut-off system was devised in the course of the development of the DaimlerChrysler 5.7l engine. This highly complex system shows how many influencing parameters have to be taken into account if satisfactory running behaviour is to be achieved. The lecture described engine and component design in detail. It also illustrated the functions of the system and the effect of cylinder cut-off on vehicle integration and fuel consumption.

6 Exhaust Gas Aftertreatment

Dipl.-Ing. C. Enderle (lecturer), **Dr.-Ing. H. Breitbach**, **Dipl.-Ing. M. Paule**, **Dr.-Ing. B. Keppeler**, DaimlerChrysler AG, Stuttgart: “Selective Catalytic Reduction with Urea – The Most Effective Nitrous Oxide Aftertreatment for Light-Duty Diesel Engines”:

The classical trade-off between particulate and nitrous oxide emissions has become much less important through the widespread use of particulate traps. Due to more stringent future nitrous oxide legislation two new trade-offs become more important: the hydrocarbon vs. NO_X trade-off and the fuel consumption vs. NO_X trade-off. Both excellent driveability and low fuel consumption have been key for the market success of the diesel engine. Thus, the impact of the aftertreatment system on fuel consumption is extremely important for Mercedes-Benz. Additionally, the efficiency of aftertreatment is another key factor so that engine related NO_X reduction can be limited to a great extent to measures that do not result in fuel economy disadvantages. The system that best meets these requirements is the SCR Urea Aftertreatment. It is based on the selective catalytic reduction of nitrous oxides with ammonia, which is generated by thermal decomposition of urea sprayed into the hot exhaust gases. The system has an excellent efficiency over a wide temperature range, shows good lifetime stability, and additionally permits good packaging, Compared to other systems, it does not have a negative impact on hydrocarbon emissions. Due to its high efficiency, engine-out nitrous oxide emissions can remain relatively high, which limits the impact on engine fuel efficiency. Through careful optimisation, it was possible to lower urea consumption to such an extent that sufficient urea is available for operation during service intervals. Thus the system is not visible to customers and requires no extra effort, such as the filling or refilling of urea.

Dipl.-Ing. W. Maus (lecturer), **Dipl.-Ing. R. Brück**, Emitec Gesellschaft für Emissionstechnologie mbH, Lohmar: “The Future of Heterogeneous Catalyst Technology for Passenger Cars “Turbulent” Catalysts for Gasoline and Diesel Engines”:

The development of catalyst technology for automotive engineering applications started in the 60s with the adoption of highly efficient pellet catalysts used in the chemical industry. These catalysts showed very high mass transfer rates comparable to those under turbulent flow conditions. Mechanical vibrations and gas pulsations caused abrasion. This is why this type of catalyst was not further developed, and methods were sought to heighten durability. First, metallic honeycomb structures like those employed in refinery processes were used. However, these foil-type substrates did not prove durable either as foil joint technologies for creating monolithic structures were not yet available at that time. Monolithic ceramic honeycomb structures came later. Their straight channels were coated with catalytic materials. Monolithic honeycomb structures have a specific disadvantage: laminar channel flow restricts mass transfer and thus impairs volume-specific catalyst efficiency. Recent developments in catalyst technology for gasoline and diesel engines take full advantage of turbulence effects. The conversion of limited exhaust gas components is based on the mechanism of turbulent mass transfer. The lecture described the underlying laws applied to the use of catalysts in automotive engineering and presented the relevant test results.

Dr. M. Ivanisin (lecturer), Magna Steyr Fahrzeugtechnik AG & Co KG, Graz; **a.o. Univ.-Prof. Dr. S. Hausberger**, Technial University Graz: “Particle Number Emissions – Measurement and Global Simulation”:

The lecturer demonstrated a method using simple interactions for designing a model for the calculation of particle number emissions. Based on measurements performed on different engines, the lecturer explained, total particle number emissions must be understood as a function of fuel consumption and engine speed.

Thanks to suitable standardisation of measured particle number emissions, this model showed a relatively uniform particle number emission behaviour (number of particles per hour) of all tested engines and in all load points. The calculated results obtained with this model are verified through measurements of particle number emissions of passenger cars and commercial vehicles in actual operation. This method could be applied to environmental emissions modelling and diesel particulate trap applications.

7 New Diesel Engines 1

Dipl.-Ing. R. Bauder (lecturer), **Dipl.-Ing. A. Fröhlich**, **Dr. M. Gruber**, **Dr. H. Hoffmann**, **Dr. W. Wimmer**, Audi AG, Neckarsulm; **Dipl.-Ing. W. Hatz**, Audi AG, Ingolstadt: “Audi’s New 4.2 l V8-TDI”:

Audi’s new 4.2l V8 TDI engine is a consistent further development of the 4.0l TDI engine with which the Audi A8 was equipped to date. In the 4.2l engine, the cylinder sparing was increased from 88 to 90 mm and the injection system was changed over the piezo technology. The exhaust-gas recovery system, the combustion chamber and the turbocharger were further optimised. For the first time, a double-flow particulate trap was integrated. In addition, the weight of the new engine was reduced by 15 kg as compared to the 4.0l TDI.

The new V8-TDI has a maximum power output of 220 kW and a torque of 650 Nm. Thanks to the combination of diesel particulate traps, the engine meets the Euro 4 exhaust emission limits.

The engine is a member of the new Audi-V-engine family which is characterised by short and compact design and boasts numerous synergies resulting from the combination of features of gasoline and diesel engines.

Dipl.-Ing. W. Mattes, **Dr.-Ing. P. Nefischer**, **Ing. F. Steinparzer** (lecturer), BMW Motoren GmbH, Steyr: ”Redesigned Diesel Engines for the BMW 7 Series“:

In Europe, the trend towards engines with high performance and low fuel consumption has persisted in the upper range segment of passenger cars. In response to this trend and in an effort to offer its customers state-of-the-art technology, especially in this class of cars, BMW fundamentally revised both diesel engines of the 7 series in the course of its ongoing model updating programme.

In addition to improving engine performance and lowering fuel consumption, BMW focused, in particular, on modifications to meet Euro 4 emission limits as well as on a significant reduction of the weight of both engines.

Whereas in the six-cylinder engine, the dimensions remained essentially unchanged, the displacement of the eight-cylinder engine was significantly increased.

Alongside a large number of optimisations of details for weight reduction, the redesign concentrated mainly on the changeover to an aluminium crankcase, the introduction of the third generation common rail injection with piezo technology and the use of catalytically coated particulate traps.

Thanks to the thorough redesign of these engines, BMW diesel engines of the 7 series continue to occupy a leading position amongst competitors.

Dipl.-Ing. G. Doll (lecturer), **Dr.-Ing. J. Schommers**, **Dr.-Ing. A. Lingens**, **Dipl.-Ing. M. Düsmann**, **Dipl.-Ing. H. Fausten**, **Dipl.-Ing. R. Noell**, **Dipl.-Ing. C. Spengel**, **Dipl.-Ing. H. Finkbeiner**, DaimlerChrysler AG, Stuttgart: "The OM 642 Engine – A Compact, Light-Weight, Universal High-Performance Engine from Mercedes-Benz":

With the OM 642 engine Mercedes-Benz engineers have developed a high-quality and very compact V6-LDV-diesel assembly which, due to its concept and design, can replace the previous 5- and 6-cylinder in-line engines in all vehicle model series.

The basic objectives were:

- a specific output of 55 kW / litre displacement
- a specific torque of 170 Nm / litre displacement
- an installation weight similar to the inline 5-cylinder engine to be replaced
- packaging space in accordance with the in-line 5-cylinder engine to be replaced
- compliance with Euro 4 emission legislation even without a particulate trap
- use of a third-generation injection system with piezo-injectors and high injection variability for optimized combustion management in terms of emissions and noise.

The lecture illustrated the concept and technological features of the new engine and presented a comparison of engine data, driving performance and fuel consumption rates of the new engine and its predecessor versions used in the C-class.

In addition to engine characteristics, stringent Euro 4 emission limits applying today must be met, Hence the exhaust gas system plays an important role in engine design. Although the current Euro 4 emission limit can be met without particulate traps, in many parts of Europe production vehicles will be fitted with particulate traps.

The lecturer also described the particulate traps developed by DaimlerChrysler and explained the company's regeneration concepts which require no additives.

The high investments made in a DaimlerChrysler plant in Berlin, where the new engine is produced, underline the company's clear commitment to Germany as the location for manufacturing its products.

8 Simulation / Combustion Phenomena

Ing. P. Martinelli (lecturer), **Ing. N. Cavey, Ing. L. Fraboni**, **Ing. M. Bollini**, Ferrari Gestione Sportiva, Maranello; **Dr. P. Schöggl** (lecturer), **Dipl.-Ing. F. Mundorff**, **Dipl.-Ing. M. Dank**, AVL List GmbH, Graz: "Formula One Engine Development with New Simulating and Testing Methods":

The presentation illustrated the uniform use of a real-time simulation model in the development areas office, test bench and race track. Real-time capability, which constitutes a prerequisite for test bench work, also offers advantages for office and race track studies due to higher efficiency as several simulations can be carried out in a time unit. The greatest benefit of this model results from the high speed, at which model parameters can be transferred and from improved communication amongst the development teams.

The paper described the combination of real-time simulation and automated calculation for hundreds of engine and vehicle relevant performance parameters (metrics), as well as a powerful optimising route as the closed loop approach. The automated parameter calculation speeds up the data analysis process by a factor of 5000. Accordingly, a significantly higher efficiency is achieved in the developing process. Still, the objective parameters constitute only the basis for an automated, computer supported optimisation process.

The application of these methods in the Ferrari Formula One Engine Development was illustrated on the basis of recent examples.

Dipl.-Ing. W. Nietschke (lecturer), **Dipl.-Ing. M. Schultalbers**, **Dr.-Ing. O. Magnor**, IAV GmbH, Gifhorn: "The Growing Influence of Simulation in the Design of Engine Control Systems":

The use of new technologies in the design of engines is driven by a number of requirements, such as the need for the reduction of fuel consumption, emission levels and production costs.

In order to be able to take full advantage of these concepts in series production, efficient engine management appears indispensable. The time spans allotted to the development of functions and applications are becoming ever shorter and the complexity of processes is rising enormously.

Thus in all development phases of engine management new challenges present themselves which can only be met by adopting modern simulation-based approaches and applying state-of-the-art control engineering methods. Through the consistent use of simulation throughout all process steps, from system and function development to application, efficiency can be raised markedly and the overall development process accelerated considerably.

The tool-based configuration of the sensor-actuator-concept results in optimized system solutions. The know-how of model structures gained through offline simulations can be incorporated into ECU functions through model reduction techniques. The structural equivalence of the simulation platform and the ECU platform ensures the development of efficient application tools and methods. This can start at early stages of the development process. Automated application processes resolve the tradeoff between cost and quality.

Dipl.-Ing. G. Prochazka (lecturer), **Dr. P. Hofmann**, **Univ.-Prof. Dr. B. Geringer**, Technical University of Vienna; **Dipl.-Ing. J. Willand**, **Dr. C. Jelitto**, **Dipl.-Ing. O. Schäfer**, Volkswagen AG, Wolfsburg: "Autoignition in a Highly Supercharged Engine and Preventive Measures":

For a successful implementation of a downsizing-concept for a SI engine it is essential that high supercharging pressures and high torques are available already at low engine speeds. During investigations of a supercharged 4-cylinder-gasoline engine auto ignition occurred which prevented high boost rates at low engine speeds. By means of optical measurement and observation techniques it was possible to identify the cause of auto ignition. Bad mixture formation, which caused the formation of a fuel wall film in the combustion chamber, triggered auto ignition.

The most effective measure to prevent auto ignition consists in avoiding the formation of a fuel wall film in the combustion chamber. To this end, mixture preparation and charge motion must be optimised in such a way as to minimise or eliminate the wetting of the wall with fuel.

9 New Gasoline Engines 2

Dr.-Ing. P. Kreuter (lecturer), **Dr. B. Gand**, **Dipl.-Ing. S. Wegner**, **Dipl.-Ing. U. Schaffrath, Dr.-Ing. M. Wensing,** Meta Motoren- und Energie-Technik GmbH, Herzogenrath: "The Turbo-Charged SI Engine with Variable Compression Ratios: Effects and Potentials":

In this presentation, the potential of a SI engine concept based on a combination of variable compression and supercharging was described. Two variable compression systems – one continuously variable and the other being a two-step system – were presented. With both systems the compression ratio can be adjusted to thermodynamic engine requirements over the entire operating range. The lecture treated, in detail, variable compression in SI engines, and especially in combination with high supercharging rates. Test bench results were analysed and compared with measurements obtained from extensive investigations of vehicles in practical operation.

The afore-mentioned systems permit a variation of compression ratios under part load which has a positive impact on engine efficiency, emissions and smoothness. Reduced ignition delay and higher combustion speed result in increased exhaust gas recovery rates and thus in lowering NO_X emission levels despite higher compression. A reduction of compression under full load counteracts knocking. During cold starting, variable compression combined with late ignition generates higher exhaust gas temperatures thus shortening the time required for warming-up the catalyst.

The combination of variable compression and supercharging assures high specific mean pressure rates with high performance, while thermal and mechanical load limits are not exceeded. Therefore, these systems can be used selectively and efficiently for downsizing.

T. Hirai (lecturer), **C. Keisuke**, Nissan Motor Co., Ltd., Kanagawa, Japan: "Nissan's New Generation of Small and Medium Four-Cylinder Gasoline Engines":

Two brand-new small to medium ranges of 4 cylinder gasoline engines have been developed jointly by Nissan and Renault. These two segments cover a 1.5 – 1.6 litre version (=HR engine) and a 1.8 – 2.0 litre version (=MR engine). The HR engine and the MR engine share a host of new technologies and are designed to provide excellent fuel economy combined with improved acceleration performance under the conditions most commonly encountered in everyday driving. Specifically, the adoption of the following new technologies has substantially improved fuel economy and middle- to low-end torque under ordinary driving conditions:

- significant reduction in mechanical frictions thanks to an innovative machining method for the cylinder bores and further improvement of a mirror-like finish to the crankshaft and cam bearing surfaces
- thermal efficiency improvement by strengthening the gas flow and cooling efficiency in and around the combustion chamber.

Improvements of some technologies led to best-in-class weights and compactness of the new engines.

In designing these two engines, special attention was given to improving the basic potential performance characteristics such as thermal efficiency and friction.

As a result, these two brand-new engines will constitute the basis for further innovations in direct injection and turbocharging technologies etc.

T. Nara (lecturer), **T. Kusunoki**, **N. Sugita**, Toyota Motor Corporation, Aichi-ken, Japan; **E. Mishima**, Daihatsu Motor Company LTD., Osaka, Japan: "A New 3-Cylinder 1.0 l Engine Development for Light Weight and Good Fuel Economy":

In order to meet the requirements for CO_2 emission reduction, Toyota and Daihatsu have jointly developed the 1KR-FE new 3-cylinder 1.0 l gasoline engine. Beside excellent fuel economy, the development targets for this new engine were: top class performance, light weight and compactness. In addition to friction reduction obtained by using only three cylinders instead of four, benefits were gained by using thin piston rings with low tension. A new type of resin coat on the piston skirt also contributes to lower friction. As a result of these four improvements, the new Toyota Aygo emits merely 109 g/km CO_2.

Thanks to the optimisation of the combustion chamber design and the introduction of variable valve timing VVT-i a maximum power output of 50 kW and a maximum torque of 93 Nm were achieved. Also a low-speed torque of 85 Nm is already available at 2000 rpm. All intake air system components are made of plastic in order to reduce engine weight and to permit highly integrated packaging. A newly developed cast iron liner with small wall thickness resulted in only 7 mm spacing between cylinder bores which also contributed to the compactness of the engine. In an effort to reduce the vibration level the weight of moving parts was reduced, the rigidity of the cylinder block was increased and a crankshaft with 3 counter weights was developed. Improved engine mountings combined with a torque rod system minimise idle speed vibration.

10 Combustion

Dipl.-Ing. O. Lang (lecturer), **Dr.-Ing. K. Habermann**, FEV Motorentechnik GmbH, Aachen; **Prof. Dr.-Ing. S. Pischinger**, **Dipl.-Ing. F. Fricke**, RWTH Aachen: "Gasoline Combustion with Future Fuels":

This paper described the demands and potentials of current and future gasoline combustion systems with regard to the fuels gasoline, natural gas and hydrogen. First, fuel specifications that are crucial for the spark ignition process were compared. These are reflected by the parameters determined by the combustion process. Potentials for the compensation of power loss, efficiency improvement and emission reduction using alternative fuels were discussed, taking into account fuel-specific properties.

Whereas with natural gas full load drawbacks can be reduced to less than 5 % as compared to gasoline by combustion system tuning, hydrogen operation with port injection leads to reductions of about 25–30 %. These drawbacks can be compensated through boosting, where both methane and hydrogen are suitable because of their burning characteristics.

Compared to λ=1 operation, hydrogen offers efficiency benefits of up to 30 % over a wide range of the engine map due to quality control. In hydrogen operation, combustion at air-fuel ratios of 2 to 2.5 is nearly NO_X-free. Thanks to the combination of lean combustion and boosting, an indicated mean effective pressure of about 15 bar (peak pressure limited) with indicated specific consumption of close to 200 g/kWh and indicated specific NO_X emissions of less than 0.5 g/kWh were achieved. Direct injection will lead to further improvements of mean effective pressure levels.

The results obtained in engine tests have shown that combustion systems can be devised which, with no or only minor modifications, can operate with different fuels. An optimum "flexfuel" concept can be developed with variable compression ratios (VCR).

Dr. P. Bartsch (lecturer), **Dipl.-Ing. P. Gutmann**, **Dipl.-Ing. T. Kammerdiener**, **Dipl.-Ing. M. Weißbäck**, AVL List GmbH, Graz: "The Future Passenger Car Diesel Engine Emission Reduction Combined with Excellent Driving Characteristics":

Diesel engines for passenger cars are facing a triple challenge: they must comply with most stringent emission standards, be cost-effective in operation and show an excellent driving performance. Without a further reduction of raw emissions, the application of a four-way catalyst (for CO, HC, particulate and NO_X emissions) will be indispensable in order to be able to comply with future emission limits. When raw emissions can be significantly lowered i.e. by means of alternative combustion processes with cylinder-pressure guided combustion control and/or the application of optimised supercharging systems, an exhaust gas aftertreatment concept consisting of an oxidation catalyst and a particulate trap will be sufficient for certain vehicle and engine combinations. Charge conditioning and mixture homogenisation required for emission control are achieved by means of the geometrical compression ratio, the boosting and EGR systems and fuel injection management. The engine control input should be extended by at least one combustion signal.

Dr.-Ing. L. Ruhkamp (lecturer), **Dr.-Ing. M. Krüger**, FEV Motorentechnik GmbH, Aachen; **Dipl.-Ing. S. Schönfeld**, RWTH Aachen: "Measures for Lowering Raw Emissions of Commercial Vehicle Diesel Engines":

The audience was informed that the reduction of oxygen concentration in the intake air through exhaust gas recirculation plays a dominant role in lowering NO_X emissions. Especially with very low nitrogen raw emissions, additional measures aimed at reducing NO_X emissions can be neglected. However, some positive factors can be identified for the reduction of all other emissions and for better fuel economy. On the air side, gas density in the combustion chamber is a particularly crucial parameter, regardless of whether gas density is increased by temperature control or by means of pressure changes. With both methods, particulate emissions and fuel consumption can be influenced in a very positive way. If boost pressure is raised it is extremely important to assure very careful tuning of the combustion process and the air management system of the engine. This principle also applies to another air parameter, swirl, which, if properly tuned to the combustion process, also has a positive effect on fuel consumption and particulate emissions. Another approach to efficient emission control at very low oxygen concentrations in the intake air are the hydraulics and the injection system. Particularly favourable results can be obtained when injection timing is advanced and the injection pressure raised. Injection curves also play a significant role in fuel consumption and particulate emissions. Ramp-type injection curves indicate both favourable emission behaviour and high fuel economy. In addition, it was shown that split injection during the main injection phase has an extremely positive effect on particulate emissions also when NO_X emissions rise further in the presence of extremely low oxygen concentrations of the intake air. Together with excellent fuel economy, this approach offers a very promising option for the reduction of emissions. The main problem, however, consists in the homogenisation of the fuel-air ratio over the widest possible range of the engine map

11 New Diesel Engines 2

Dr. H. Sorger (lecturer), **Dr. W. Schöffmann**, **Dipl.-Ing. F. Zieher**, **Dipl.-Ing. U. Sauerwein**, **Dipl.-Ing. F. Schweinzer**, **Dr. P. Herzog**, AVL List GmbH, Graz: "AVL Genios LE – A 3-Cylinder Lightweight Magnesium Diesel Engine as Part of an Engine Family for Hybrid and High Performance Powertrain Systems":

The ever higher power density of engines acts as a significant driver for innovations; however, stringent exhaust gas legislation imposes strict limits on current developments. Weight reduction is a central goal as it contributes significantly to the reduction of fuel consumption of passenger cars.

The lecture showed the design principles applying to the modular systems used in light-weight composite material concepts can be employed as high-performance engines, in-line or V-type diesel engines, with extremely high power densities as well as hybrid applications with different numbers of cylinders and varying displacements.

A supercharged three-cylinder diesel engine was presented as an example for this type of technology and its design concept was explained. One engine which consists of aluminium composite material is designed for a maximum ignition pressure of 180 bar, and the other engine, which consists of magnesium composite material, is designed for a maximum ignition pressure of 150 bar.

The details and system optimisation of the crankcase of the AVL Genios LE, a three-cylinder lightweight magnesium diesel engine, which belongs to this engine family and was designed for maximum fuel economy, were illustrated. In combination with a mild hybrid version this engine serves as drive for AVL's vehicle ECO-Target.

M. Suzuki (lecturer), **N. Tsuzuki**, **Y. Teramachi**, Toyota Motor Corporation, Aichi-ken, Japan: "The New Toyota 4-Cylinder Direct Injection Diesel Engine – Toyota's D-4D Clean Power Concept":

Environmental protection calls for a global approach; in automotive engineering, the focus is on low exhaust gas and CO_2 emissions. At the same time it is expected that a high-performance engine should offer driving pleasure. Against this background, Toyota has developed two versions of a new 2.2 litre common rail diesel engine: the 2AD-FTV and the 2AD-FHV.

The 2AD-FTV is fitted with an aluminium cylinder block, a balancing shaft, a roller-rocker valve train, and solenoid injectors. As compared to the predecessor engine, this engine has higher maximum power and lower weight.

The 2AD-FHV boasts additional advanced technologies, such as a lower compression ratio, a piezo injector common rail system operating at high injection pressure (180 MPa), DPNR-technology, a switchable EGR cooling system, etc.

With the aid of these technologies, nitrogen oxide emissions were drastically reduced far below the limit value stipulated in the Euro 4 Directive, while at the same time this engine, due to its maximum power and torque, occupies a leading position in the 1.9 to 2.2 litre displacement category. Production and marketing of this engine will start in 2005.

Dr.-Ing. H. Endres, **Dr.-Ing. J. Hadler** (lecturer), **Dipl.-Ing. H.-J. Engler**, **Dipl.-Ing. R. Dorenkamp**, **Dipl.-Ing. H. Jelden**, **Dipl.-Ing. H. Stehr**, Volkswagen AG, Wolfsburg: "Volkswagen's New 125 kW-4-Cylinder Diesel Engine with Piezo Unit Injector":

Two and a half years after the release of the first four valve TDI engine with unit injectors and a power output of 103 kW, a new, more powerful engine version with 125 kW is available. The new four-cylinder engine, which has a displacement of 2.0 litres, boasts a number of outstanding features such as its new piezo-unit-injector high pressure injection system, a balancing shaft, and a service-free diesel particulate trap arranged closely to the engine. The new piezo-unit injector permitting injection pressure rates of up to 2.200 bar, contributes to significantly increased power output and, at the same time, to markedly lower pollutant emissions. In addition, specific fuel consumption was further reduced due to the improved efficiency of the injection system. Thanks to the piezo technology a noticeable reduction of injection noise, and thus also of external noise during idling, was achieved. Numerous other innovations, including an advanced camshaft drive, new ceramic heater plugs and an improved oil separation method, have added to customer benefit and better exhaust gas quality. The first cars to be equipped with this engine, which will be installed laterally, will be the Passat and subsequently the Golf platform. Audi models of the B class will later also be fitted with this engine in a longitudinal installation. At a specific power output of 63,5 kW/l, the new TDI is best-in-class in the four-cylinder engine category. In addition to excellent driving performance, customers will benefit from extremely low fuel consumption, maximum environmental friendliness as well as considerably improved noise behaviour and vibration characteristics.

12 Transmissions / Acoustics

Dipl.-Ing. K.-H. Bauer (lecturer), **Dr.-Ing. J. Heinrich**, **Dr.-Ing. F. Günter**, BorgWarner Drivetrain Engineering GmbH, Ketsch: "Potential Fuel Efficiency Improvements due to Dual Clutch Transmission":

The market penetration of automatic transmissions in passenger cars is far deeper in the US and Japan than in Europe. Alongside higher purchasing prices, the main reason for the lower popularity of automatic transmissions in Europe has been customers' demand for better fuel economy.

With the series production of dual clutch transmissions it has been possible for the first time to offer an automatic transmission which consumes less fuel in actual driving than manual transmission systems. As compared to other transmission concepts, parasitic losses in the clutch system are significantly lower.

The lecture compared system-immanent power losses of different transmission concepts and analysed their effects on fuel consumption.

On the basis of vehicle and test bench results as well as system simulations using comprehensive test data, the advantages of dual clutch transmissions were described.

The potential for further heightening the efficiency of dual clutch transmissions was analysed on the basis of system development results and concepts devised by BorgWarner research and development.

When the engine and transmission are investigated as a unit, i.e. the vehicle powertrain, customer-relevant findings will permit a further improvement of fuel economy.

Dipl.-Ing. J. Kiesel (lecturer), **Dr.-Ing. J. Greiner**, **Dr.-Ing. A. Veil**, **Dipl.-Ing. J. Strenkert**, DaimlerChrysler AG, Stuttgart: "Mercedes Benz' New Front Wheel Drive CVT Autotronic":

The new CVT Autotronic transmission was specially developed for the powertrain of the A class successor model. Thus Mercedes Benz has set new standards in terms of convenience and fuel consumption in the compact car category. Additional development efforts focused on higher output, higher torque, greater driving pleasure and very compact dimensions. As compared to the predecessor model the output of gasoline and diesel engines was raised by up to 38 per cent, and maximum torque was raised by up to 46 per cent.

The new innovative Autotronic is a belt-driven CVT (continuously variable transmission) which permits variable ratio selection by means of a pully variator and steel thrust belt.

The outstanding ratio spread, the enhanced overall efficiency of the engine-transmission unit and the new driving strategy devised have generated marked improvements with respect to driving comfort, noise behaviour, responsiveness and acceleration as well as fuel consumption and exhaust gas emissions.

Dr. G. Heinz (lecturer), **Dipl.-Ing. G. Heilmann** GFal e.V.Berlin (Society of the Promotion of Applied Informatics); **Dr. H. Schulze**, **Dipl.-Ing. S. Brusius**, **Dipl.-Ing. W. Krechberger**, **Dipl.-Ing. G. Schumann**, DaimlerChrysler AG, Stuttgart: "Application of an Acoustic Camera for the NVH Optimisation of Engine and Powertrain":

The acoustic optimisation of engines and powertrains requires much time, experience and craftsmanship on the part of acoustic engineers. The passing on of information to staff in other departments such as design and testing, as well as to decision-makers and suppliers, is a major challenge. In this process, tools for analysis and visual representation of acoustic phenomena are needed. Since 2003 DaimlerChrysler has been using acoustic camera equipment in its NVH department for engine and powertrain studies. The lecture presented the pros and cons of this new technique as well as its potential and limits. By way of introduction, the lecturer gave a brief outline of the history of acoustic imaging in Daimler and GFal.

13 Supercharging of Gasoline DI Engines

Dr.-Ing. M. Klüting, **Dipl.-Ing. S. Missy**, **Dr.-Ing. C. Schwarz** (lecturer), BMW Group, Munich: "The Potential of Spray-Guided Petrol Direct Injection in Combination with Turbocharging":

The spray-guided DI combustion process developed by BMW allows tapping the potential of new material parameters and modified process control in lean stratified combustion. With a performance potential clearly exceeding 60 kW/dm³ and fuel consumption that is 20 % lower than that of conventional gasoline engines, this engine offers considerable benefits to customers.

The DI combustion system constitutes a new basic technology for gasoline engines which will take advantage of many new options in the design of gasoline engines. In combination with an innovative turbocharging technology and double VANOS, this DI process redefines the power output and fuel consumption levels of gasoline engines while preserving the specific virtues of gasoline engines, such as a wide rpm range and high responsiveness.

The lecturer illustrated concept analyses of the combination of this combustion process with innovative supercharging procedures.

Dipl.-Ing. P. Lückert (lecturer), **Dipl.-Ing. J. Frey**, **Dipl.-Ing. R. Kemmler**, **Dipl.-Ing. U. Schaupp**, **Dipl.-Ing. G. Vent**, **Dipl.-Ing. A. Waltner**, DaimlerChrysler AG, Stuttgart: "Customer and Future-Oriented Gasoline Engine Technologies – Today and Tomorrow":

Efforts in the development of gasoline engines with their excellent comfort and emission characteristics, high output and low cost operation will concentrate on bringing down fuel consumption further.

High-performance direct injection systems combined with turbocharging will sustainably heighten the attractiveness of gasoline engines, owing to fuel efficiency, higher output and increased torque.

In addition to further development of the four-cylinder downsizing concept based on supercharging and first generation direct injection, which has been successfully marketed by Mercedes Benz since 2002, the second generation spray-guided injection – thanks to the use of high-performance injection components – has permitted a decisive improvement of the combustion process and a significantly higher, directly perceivable fuel economy which is derived from improved stratified combustion.

This new direct injection system can be regarded as a stand-alone technology. The development of a highly efficient exhaust gas aftertreatment system for lean-burn operation presents major challenges.

Together with turbocharging, these innovations will take advantage of further options to reduce fuel consumption while increasing driving performance markedly.

Alongside engine design activities, the lecture also briefly addressed the potential offered by alternative fuels.

Dr. G.K. Fraidl (lecturer), **Dr. P. Kapus, Dr. W. Piock**, AVL List GmbH, Graz: "The Turbocharged GDI – A Competitor of Diesel Engines?":

The combination of direct injection and turbocharging not only constitutes the basis for the success of diesel engines but also permits the application of efficient consumption concepts offering high customer benefits. Even with proven technologies such as homogeneous direct injection, double continuously variable cam phaser and single-scroll turbocharger with fixed geometry, a cost efficient consumption concept has been devised that has resulted in CO_2 emissions similar to those of diesel engines but better performance and markedly lower production costs.

Alongside the improved efficiency thanks to a double cam phaser, high charge motion and direct injection, a shift to higher loads has permitted a reduction of fuel consumption not only in NEDC tests but also in customer operation. The best trade-off between fuel economy and vehicle dynamics especially during starting is achieved through the combination of a significantly longer drive ratio and only moderate downsizing. In an effort to assure the acceptance of a longer drive ratio by customers, not only steady state and transient torque behaviour had to be improved considerably in the low speed range, but also the performance characteristics had to be adjusted to a lower nominal speed (4300 rev/min) and constant power over a wide speed range.

By shifting engine operation towards higher loads, efficiency in the higher load range had to be improved. Whereas most fuel economy technologies for gasoline engines offer hardly any benefits in the high load range, fuel economy can be improved by up to 4 % thanks to a combination of the basic configuration with a relatively simple externally cooled EGR.

The fuel economy concept chosen does not offer the option that is associated with maximum technology input and high costs, but focuses on a most cost efficient volume engine which represents a genuine alternative to diesel engines in terms of CO_2 emissions, driving performance and cost efficiency.

14 Acoustics

Dipl.-Ing. A. Enderich (lecturer), **Dipl.-Ing. K. Brodesser**, **Dipl.-Ing. L. Fröhlich**, **Dipl.-Ing. S. Bender**, Mahle Filtersysteme GmbH, Stuttgart: “Sound-Engineering of Supercharged Engines”:

Owing to their design concept, supercharged engines are characterised by higher damping of the intake noise than naturally aspirated engines. A charge-air cooler, a compressor and a long intake duct produce a considerable reduction of sound emissions. As a result of the additional damping of these components, the characteristic engine orders are much less pronounced than in naturally aspirated engines. Furthermore, due to the damping of these components in the intake air duct, orifice noise is hardly influenced by load and engine speed. The performance of these engines cannot be measured on the basis of an acoustic feedback. A downsizing of the damping element air filter does not suffice in order to improve engine sound.

Therefore, Mahle developed an engine sound system which can also be used for supercharged engines. This system consists of a side branch arranged between the intake manifold and the charge-air cooler. The side branch leads to a resonance volume with an elastic membrane which was specifically designed for excessive positive pressure. By varying duct length and diameter, resonance volume and membrane properties, the sound in the car interior can be modified and any desirable sound characteristics can be created. It is very impressive to see how the emotional appeal of a vehicle can be heightened by means of such an engine sound system and how driving fun can be heightened thanks to sound.

Figure 10: Dr. Thomas Weber, DaimlerChrysler AG

Figure 11: Masatami Takimoto, Toyota Motor Corporation

Figure 12: Prof. Dr. Martin Winterkorn, Audi AG

Dr.-Ing. W. Wenzel (lecturer), **Dipl.-Ing. M. Alex**, Mann+Hummel GmbH, Ludwigsburg: “Symposer – Sound Design for Vehicles with Supercharged Engines”:

Whereas in the past attention was primarily focused on noise reduction, today vehicle acoustics serve as a perceivable distinction mark between different vehicles which are relatively similar with regard to their technological features. In the sound design for the vehicle interior, the air intake system offers many options for influencing the acoustics inside a car. In turbocharged engines, the characteristic noise generated by pulsations in the intake manifold are lost because of the damping effect of the intercoolers and compressors in the loss pressure range and in the orifice. Special acoustic systems have been devised to transfer specific sounds generated by the intake pulsations in the high pressure range into the vehicle interior. The symposer which acts as an acoustic transmission device was developed in co-operation with DaimlerChrysler in order to perform this function.

Prof. Dr. U. Bernhard (lecturer), Adam Opel AG, Rüsselsheim; **Dr. N. Alt**, FEV Motorentechnik GmbH, Aachen: “Objectivity of Subjective Acoustic Phenomena”:

Engines and auxiliary units frequently generate unpleasant, disturbing noise components, which can destroy positive impressions of customers get such as “a low, pleasant, harmonious sound”.

The first important step towards avoiding such disturbing sound phenomena is a common, defined and standardised language and a catalogue of these phenomena grouped together by sound categories or sound families which combine subjective criteria and objective findings from analyses. A good sound basis was created by the FCC project „Evaluating and Cataloguing Disturbing Sounds of Internal Combustion Engines”.

Figure 13: Contended faces at the end of the Symposium

The next step consists of assessing subjectively perceived noise annoyance on the basis of measured or calculated time series of acoustic signals. Once this has been done, disturbing noise can be identified, corrected and avoided already at the design phase of the engine.

In a joint project of Adam Opel AG and FEV Motorentechnik a characteristic sound of modern internal combustion engines was assessed both subjectively by an expert team and by means of mathematical studies, which reflected the subjective perceptions. The results were validated by means of another type of sound from the same sound family.

Thus it has been possible to prove that it is basically feasible to objectify subjective acoustic phenomena on the basis of time series.

Conference Documentation

The in-extenso lectures presented at the 26th International Vienna Motor Symposium are contained in the VDI Research Reports, series 12, no. 595, volumes one and two (including CD) and supplements. This documentation can be obtained from the Austrian Society of Automotic Engineers (ÖVK).

Invitation

You are cordially invited to participate in the 27th International Vienna Motor Symposium on April 27 and 28, 2006 at the congress centre of the Vienna Hofburg. We urgently recommend you to apply at the earliest possible time, immediately after the publication of the programme on the Internet at the end of December 2005.

Contact

Österreichischer Verein
für Kraftfahrzeugtechnik (ÖVK)
Elisabethstraße 26
A-1010 Vienna

Tel. +43/1/585 27 41-0
Fax. +43/1/585 27 41-99
E-Mail. info@oevk.at
Homepage: www.oevk.at

15 Plenary Closing Session: The Future of Mobility

Dr.-Ing. T. Weber, Member of the Board, Mercedes Car Group, DaimlerChrysler AG, Stuttgart, **Figure 10**, "DaimlerChrysler AG: With Customer-Oriented Innovations on the Road to Sustainable Mobility":

DaimlerChrysler with its global operations acts as the driving force behind prosperity in many regions of the world. With the development, production and marketing of cars, DaimlerChrysler contributes to assuring the mobility of individuals in the long run. It is DaimlerChrysler's declared objective to reconcile the interests of society.

The first step down the road to sustainable mobility is the continuous optimisation of conventional gasoline and diesel engines, the potential for which has by no means been exhausted. Technologically sophisticated engines call for high-quality fuels. Improved and new synthetic fuels constitute important elements of this strategy. And, finally, DaimlerChrysler is continuing its intensive work on alternative powertrains. Hybrid technology is seen as an important interim step on the road to fuel cell drives, the technology of the future.

DaimlerChrysler pursues a long-term strategy in order to attain the goal of sustainable mobility.

M. Takimoto, Senior Managing Director, Toyota Motor Corporation, Aichi-Pref., Japan, **Figure 11**, "Toyota's Challenge for Sustainable Mobility":

Toyota's vision for realising sustainable mobility can be summed up in two words "zeronise and maximise". Zeronise means aiming at reducing to zero the harmful effects of vehicles on the environment, traffic accidents and congested traffic, while maximise stands for heightening the emotional appeal of driving, comfort and driving pleasure. Toyota's developments in vehicle technology seek to reconcile these two goals. The development of technology for gasoline and diesel-powered vehicles which will continue to be the main drive units in the foreseeable future has concentrated on increasing engine performance, lowering emissions, reducing fuel consumption and bringing down CO_2 emissions in particular. Various technologies, such as variable valve timing (VVT-i), direct injection in gasoline engines (D-4), advanced clean diesel systems (Toyota D-Cat) etc., have been introduced in series production. Hybrid technology has emerged as a key technology for achieving high fuel economy and thus lowering CO_2 emission and minimising pollutant emissions in general. Combining superior driving pleasure and maximum environmental friendliness, the second generation Toyota Hybrid System-II (THS-II) used in the Toyota Prius can be seen as the practical implementation of the "zeronise & maximise concept". Frequently the fuel-cell hybrid vehicle is considered as the ultimate eco-vehicle, but many problems will have to be solved before its series-production. These include the global production and availability of hydrogen. With a view to attaining sustainable mobility vehicle manufacturers must adopt a proactive approach instead of merely responding to changing requirements as they did in the past. A proactive attitude is the principal prerequisite for Toyota's motto "Today for Tomorrow".

Prof. Dr. M. Winterkorn, Chairman of the Board, Audi AG, Ingolstadt, **Figure 12**, "Individual Customers' Requirements in the Global Market – Opportunities and Challenges":

Audi responds to global requirements by adopting a selective derivatives policy. Thus individual customer's demands which vary to a great extent in the three key markets, the US, Europe, and Asia, can be satisfied in the best possible way.

In international competition amongst the major vehicle manufacturing groups, design plays a significant role. In the past, Audi placed great emphasis on design and will continue to do so in the future. The decision to buy a car because it is attractive is mostly taken within a second. This is a vital competitive advantage.

As the reduction of emissions and fuel consumption is gaining importance worldwide, Audi is pursuing three strategies in parallel: firstly, Audi will continue to make progress with the development of alternative drive concepts; secondly, it will further improve its successful TDI technology and, thirdly, it will establish an innovative combination of direct injection and turbocharging as the core technology of the future for gasoline engines. This TFSI concept is capable of satisfying both a wide range of customer requirements and the stricter legal stipulations.

With its TFSI technology, Audi is taking the logical step towards a generation of high-performance and consumption-optimised engines, and safeguarding the long-term future of "Vorsprung durch Technik".

Prof. Lenz, **Figure 13**, closed the symposium by extending an invitation to the 27th International Vienna Motor Symposium which will take place on April 27 and 28, 2006.